National Aeronautics and Space Administration

Age of the Universe: 12-20 Billion Years

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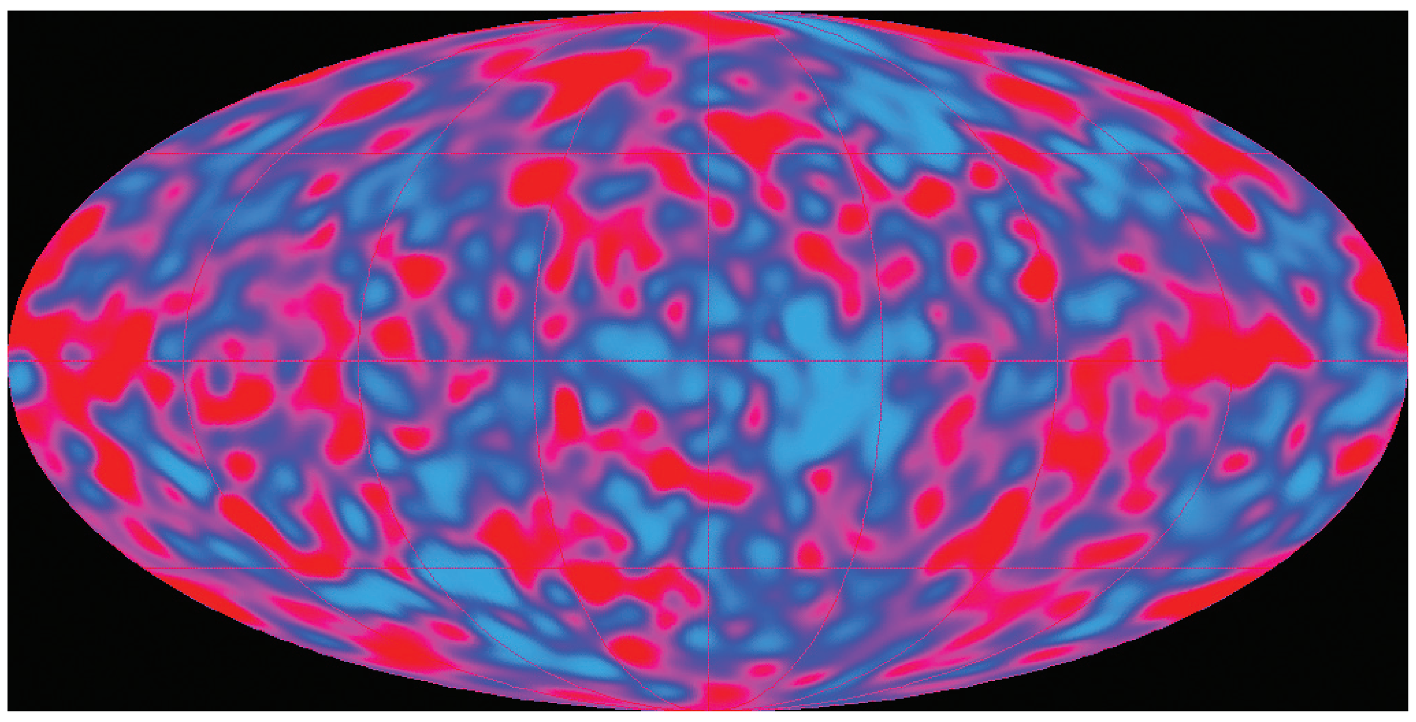
Size of the Universe: 30 Billion Light Years

Baby Universe's 1st Picture



COBE's map of the sky, showing minute fluctuations in the cosmic microwave background. Astronomers estimate that this map shows the background radiation 300,000 years after the Big Bang. (NASA image)

What did the newborn universe look like? In 1965, scientists peered into the distance with a radio telescope, and discovered a microwave background that was rather plain and featureless. Today's technology has drawn a more detailed picture of this cosmic microwave background, telling us there's a lot more to the story…and providing further evidence of the Big Bang.

"If you're religious, it's like looking at God," said George Smoot, an astrophysicist at the University of California, Berkeley and leader of the research team that unveiled the discovery. He was addressing a room packed with scientists at a meeting of the American Physical Society.

According to the Big Bang theory, the universe expanded from an unthinkably small and dense ball of energy, distributing hot radiation - and space itself - outward in all directions. As the universe expanded and cooled, this hot ball of energy produced freshly minted particles, first in the form of quarks and electrons, then protons and neutrons, which combined to make the nuclei of hydrogen and helium. Over time, gravity gathered the denser clumps of gas into the familiar galaxies, stars, and planets of the modern universe. All the while, the radiation that was emitted in all directions by that early hot gas gradually shifted into the microwave energy range as the universe expanded. We see this radiation today as a cosmic microwave background (CMB).

Data from the 1960s did not show deviations in the CMB energy across the entire sky; however, in 1967, astrophysicists Martin Rees and Dennis Sciama predicted such deviations. The subtlety of the variations- just 30 millionths of a degree - made them extremely hard to detect until NASA's Cosmic Background Explorer satellite (COBE) was launched in 1989.

Scientists have now confirmed the existence of these very slight – but now clearly measurable – energy differences. Smoot and his team created an all-sky map of these microwave variations, illustrating for the first time these anisotropies, or "lumps", in the oldest light in the universe. The COBE data shows the afterglow from the very early universe, only 300,000 years after the Big Bang. The current age of the universe is estimated at 12 to 20 billion years.

COBE excited scientists three years ago with data that exactly matched what they had expected from a Big Bang universe. COBE measured the spectrum of light from the CMB and found that it was, as predicted, in the form of a perfect blackbody curve. These data were collected by COBE on an instrument designed by John Mather of NASA's Goddard Space Flight Center, who also headed the COBE project. With the addition of the latest findings, the eight-decade-old Big Bang theory, with the addition of inflation, is now firmly the lead model for how the universe began. Other models either cannot account for COBE's results or must undertake some difficult and unsavory contortions to do so.

The lumps in the map do not correlate with anything particular in the night sky today, but they are of distinct importance, say the researchers. If the CMB was perfectly uniform, according to theory, we could not exist! So while the greatest variations in the CMB are only at a level of one part in 100,000, they are sufficient to ultimately lead to the current structures in the universe.

Princeton astrophysicist David Spergel observed at the meeting, "It's the most important discovery in cosmology in the past 20 years."

Inflation in the Universe

The Big Bang theory has a problem, say scientists. It can't go from a tiny ball of energy to the universe we see today without some help: an adjustment called inflation.

Astronomers observe that the overall temperature of the cosmic microwave background (CMB) is nearly smooth and uniform. The temperature can become uniform only if distant regions can interact and exchange energy. The fastest interactions occur at the speed of light. However, at the time the CMB radiation was emitted, two regions that are far apart on the sky today would have been separated by more than the light travel distance in the young universe. So why is the CMB temperature so nearly uniform?

Inflation Theory explains this by stating that shortly after the Big Bang, the universe underwent a very rapid expansion in a very short amount of time. This expansion grew the size of the universe by a factor of 10^{26} in about 10^{-33} seconds. Thus, regions once in contact with each other are now in far flung regions of the universe. The overall uniformity of the background temperature expanded with inflation. Particle physicists think that inflation might be a natural by-product of the transition in which the grand unified force separated into the strong nuclear force and the electro-weak force. If so, it would have occurred 10^{-35} sec after the Big Bang when the universe was 10^{27} kelvins.

After inflation, the expansion of the universe continued, but at a slower rate. As space expanded, the universe cooled and matter formed. Within the first second after the Big Bang, quarks, neutrinos, and electrons appeared, then protons and neutrons.

Inflation makes another remarkable prediction: how stars and galaxies formed in the universe. Since our cosmic neighborhood would have been microscopic in size prior to inflation, quantum fluctuations in the density of matter in this region would be stretched by inflation to astronomical proportions. After inflation, these fluctuations would be faint in contrast, but over time, the slightly over-dense regions would attract neighboring matter through the action of gravity. This would initiate the gradual process of galaxy formation. Thus inflation simultaneously explains why the CMB is so nearly, but not exactly, uniform, and ultimately how we came to be!

Scientists are now more satisfied that with the addition of inflation, the Big Bang describes the universe we live in.

Dark Matter Hunt Heats Up

The mystery of dark matter just deepened with a new report of about 20 trillion suns-worth of the invisible, unexplained stuff hiding out in a small cluster of galaxies.

The vast store of dark matter was found using the ROSAT X-ray satellite. ROSAT detected a gigantic cloud of very hot gas in a very unexpected place: the seemingly empty space between two galaxies. This cloud is a surprise because its great heat – detected from its radiation of X-rays – should have made the gas quickly dissipate.

Hot x-ray emitting gas (shown in purple) was discovered by the ROSAT satellite to be present in this group of galaxies. The presence of the gas provides evidence for the existence of dark matter. (NASA image)

The existence of the hot gas cloud can only be explained by the existence of a gravitational force to hold it in place. Only dark matter could do the job without being seen, explains Richard Mushotzky of NASA'S Goddard Space Flight Center.

What's more, the hot gas requires an amazing 30 times more dark matter than visible matter in the cluster to achieve this, said Mushotzky. The normal matter ROSAT observed is just a small fraction of what's really there.

If that sort of dark matter ratio holds true throughout the cosmos, dark matter could determine the fate of the universe. Its gravity could be enough to someday reverse the direction of matter and energy flung out by the Big Bang and pull the universe back together into a "Big Crunch," say some researchers.

An earlier case for the existence of dark matter was that made by astronomer Vera Rubin in 1970. She studied the rotation rate of stars in the Andromeda galaxy and found that it just didn't make sense. The stars in the disc further from the galactic center were not rotating more slowly than those closer in, as models predicted they should be. The simplest explanation is that matter is a lot more evenly spread through the galaxy than it appears. In other words, dark matter is tugging at these stars and keeping them in the galaxy.

Despite the new ROSAT discovery and its enormous implications, scientists haven't been very successful in figuring out what exactly dark matter is. Some think it might be a type of subatomic particle that has mass but only interacts with normal matter through gravity. These Weakly Interacting Massive Particles (WIMPs) could be shooting harmlessly through us right now, a million per second, and we wouldn't know it.

Another possibility is that the there are a lot of dark, cold dead stars out there that can't be detected with our current technology. These MAssive Compact Halo Objects (MACHOs) would probably be concentrated in the halo of stars found immediately above and below the galactic disk.

Pancake or Oatmeal Universe - What's for Breakfast?

Over its lifetime, the universe started out smooth, but has grown lumpy.

The COBE results present what's been called an isotropic, or smooth, early universe – with measured variations in the cosmic microwave background radiation of only 1 part in 100,000! You might say that, at that time, the universe was like the surface of a pancake: smooth at a glance, with differences in texture seen only under closer inspection.

The universe today is more like a bowl of oatmeal, with real "lumps" and clumps of matter and energy. Objects from planets and stars to galaxies and galaxy clusters are easily detectable. Nonetheless, overall the universe is much smoother than was predicted by the original Big Bang. This problem has been solved by inflation.

While the early universe was extremely smooth compared to today, those minuscule lumps in it were vital. Through the action of gravity, they led to the much bigger lumps we see today, the ones that make our very existence possible.

Pulsar Gravitational Waves Win Nobel Prize

This year's Nobel Prize in Physics was awarded for the amazing discovery of the first evidence, albeit indirect, for the existence of gravitational waves.

In 1974, Princeton University astronomers Russell A. Hulse and Joseph H. Taylor located PSR 1913+16, which is a special type of super-dense neutron star called a pulsar. This pulsar emits a radio pulse every 59 milliseconds as it rotates on its axis. It is locked in a dizzying eight-hour orbit with another star, which is likely to be another neutron star.

Four years later, after some careful timing measurements of the pulsar, they found that the two stars are spinning closer to each other by about three millimeters per orbit. That could only happen if something was pulling energy out of the system. But what was it?

Einstein's theory of general relativity provides the answer. It predicts that two massive objects tearing around in a strong gravitational field radiate gravitational waves out into space. This extracts energy from their orbits, and causes them to drop in closer to each other. The 8-hour orbit should be 75 microseconds shorter every year.

Russell A. Hulse and Joseph H. Taylor, both of Princeton University, shared the 1993 Nobel Prize in Physics for their discovery of evidence of gravitational waves, confirming the prediction by Einstein in 1916.

After 18 years of refinement, Taylor has honed down the timing of PSR 1913+16's orbital periods to within 0.3 percent of general relativity predictions - strong confirmation of the existence of the gravitational waves predicted by Einstein.

The pulsars won't be colliding any time soon. Although each neutron star is 7 miles in diameter and 1.4 times the mass of the Sun, they are still about a million miles apart. At their present rate, it will take 300 million years for the stars to merge.

Fool-Proofing Galactic 'Candles'

The "standard candle" used for measuring the distance to other galaxies just got a much-needed tune-up.

For years, the bright supernovae created by the deaths of white dwarf stars in binary systems, known as Type Ia supernovae, have been a standard candle. Wherever they occurred, they were believed to have roughly the same intrinsic brightness. So scientists used them to calculate the distance to the galaxies in which they occur. But recent research has revealed a way to greatly improve the accuracy of these calculations.

In the 1940s, astronomers realized supernovae came in two flavors: some (later called Type I) did not show any evidence of containing hydrogen, while others (denoted Type II) did. The lack of hydrogen means that the star has used up the basic fuel that drives nuclear reactions in stars. Type II's were found to result from the death of a single, massive star. In the 1980s, however, it became clear that some Type I's also come from the death of a massive star. The remaining Type I's, now called Type Ia, were found instead to result from the collapse of a white dwarf star in a binary star system.

In a binary system, a white dwarf can gain mass from its companion star. With sufficient mass gained from the companion, the white dwarf reaches a critical mass at which nothing can counteract the inward crush of gravity of the star on itself. The white dwarf collapses and explodes as a Type Ia supernova.

Since all Type Ia's are created by the explosion of a white dwarf star as it exceeds a critical mass, astronomers believed they should all have the same intrinsic brightness. and be useful as a measuring stick to distant galaxies. In addition, Type Ia's may be visible at distances greater than the Cepheid variable stars, identified as standard candles in 1912 by Henrietta Leavitt.

But it turns out that not all Type Ia's are equal either. A large sampling of supernovae has revealed that the pattern of brightening and fading over days – known as a light curve – varies a great deal. Astronomer Mark Phillips at the Cerro Tololo Interamerican Observatory in Chile found that the infrared light curves of some brighter Type Ia's fade more slowly over the first 15 days than do those of dimmer ones.

By sorting the dim, fast-fading supernovae from the bright, slow-fading ones, Phillips arrived at a luminosity-decline relation. It allows calculation of a correction factor for supernovae that are dimmer than the standard Type Ia supernova. Astronomers can adjust the distance accordingly, and increase the accuracy of the distance measurements.